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VARIABILITY OF THE WINTER AIR TEMPERATURE IN MID-LATITUDE EUROPE

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As long as the earth remains, seed-time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease

Genesis, Chapter VIII, Verse 22

Abstract. The aim of this paper is to report extreme winter/early-spring air temperature (hereinafter temperature) anomalies in mid-latitude Europe, and to discuss the underlying forcing to these interannual fluctuations. Warm advection from the North Atlantic in late winter controls the surface-air temperature, as indicated by the substantial correlation between the speed of the surface southwesterlies over the eastern North Atlantic (quantified by a specific Index I_{na}) and the 2-meter level air temperatures (hereinafter T_s) over Europe, 45-60°N, in winter. In mid-March and subsequently, the correlation drops drastically (quite often it is negative). This change in the relationship between T_s and I_{na} marks a transition in the control of the surface-air temperature: absorption of insolation replaces the warm advection as the dominant control. This forcing by maritime-air advection in winter was demonstrated in a previous publication, and is re-examined here in conjunction with extreme fluctuations of temperatures in Europe. We analyze here the interannual variability at its extreme by comparing warm-winter/early-spring of 1989/90 with the opposite scenario in 1995/96. For these two December-to-March periods the differences in the monthly mean temperature in Warsaw and Toruń, Poland, range above 10°C. Short-term (shorter than a month) fluctuations of the temperature are likewise very strong. We conduct pentad-by-pentad analysis of the surface-maximum air temperature (hereinafter T_{max}), in a selected location, examining the dependence on I_{na} . The increased cloudiness and higher amounts of total precipitable water, corollary effects to the warm low-level advection in the 1989/90 winter, enhance the positive temperature anomalies. The analysis of the ocean-surface winds is based on the Special Sensor Microwave/Imager (SSM/I) dataset; ascent rates, and over land wind data are from the European Centre for Medium-Range Weather Forecasts (ECMWF); maps of 2-m temperature, cloud cover and precipitable water are from the National Centers for Environmental Prediction (NCEP) Reanalysis.

Key words: anomalies of air temperature in Europe;
maritime-air advection; climatic fluctuations.

Introduction

The aim of this paper is to analyze the interannual variability which characterizes the late-winter surface temperature in mid-latitude Europe, 45-60°N, and discuss its causes. Strong variability applies as well to the timing of end-of-winter and onset-of-spring, whether measured by the beginning/end of snow-cover, or by phenological events (Woś, 1999; Jaagus and Ahas, 2000). The fluctuations have profound implications for agriculture, forestry, and indeed for the way-of-life of the large population living in these regions.

With the winter sun low above the horizon, and low absorptivity (high albedo) of the snow-covered surface, advection from the oceans effectively controls the temperatures over the adjoining continent, as shown by Rogers and Mosley-Thompson (1995), for instance. The surface of the North Atlantic is much warmer than that of the mid-latitude Europe, whereas the Arctic is colder, so that of the temperatures in Europe fluctuate with the wind direction. It is widely recognized that circulation patterns over the North Atlantic and Europe fluctuate with the North Atlantic Oscillation (NAO), the stage of which is quantified by an Index (Rogers, 1997). Recently, a specific index for quantifying the low-level flow from the North Atlantic into Europe has been developed by measuring the strength of the ocean-surface southwesterlies over the eastern North Atlantic. This index, I_{na} , apparently is a more directly relevant measure of the maritime-air advection into France and into mid-latitude strips through Europe, from France to Russia (Otterman et al., 1999).

We analyze here the interannual variability at its extreme by comparing warm-winter/early-spring of 1989/90 with the opposite scenario in 1995/96. Short-term (shorter than a month) fluctuations of the temperature are likewise very strong, so for these two December-to-March periods we conduct pentad-by-pentad analysis of the T_{max} in a selected location and our Index I_{na} .

SSM/I, ECMWF, NCEP Datasets

From the SSM/I aboard the Defense Meteorological Satellite Program (DMSP) satellites, a large dataset of surface wind speeds over the global oceans has been derived. Variational analysis method was selected to derive the wind-vector data. In this method, the SSM/I retrievals (that is, the measurements of speed) are combined with independent wind observations to produce consistent fields of wind speed and direction. The resulting global ocean-surface dataset is appropriate for climate analysis (Atlas et al., 1996).

The ECMWF dataset is part of the Basic Level III-A analysis product with the ECMWF/World Climate Research Programme (WCRP) Global Atmospheric Data Archive. In our study, we use data interpolated horizontally to the standard Goddard Laboratory for Atmospheres grid of 2.0° in latitude and 2.5° in longitude, from the ECMWF data archived on a 2.5° by 2.5° latitude/longitude grid.

Significant parts of our study are based on the NCEP Reanalysis dataset, described in detail by Kalnay et al. (1996), which extends from January 1948 essentially to the present. Improvements to the numerical weather prediction operational systems were introduced when satellite measurements become available (see Kalnay et al., 1996, for a documentation of the changes). The intent in reprocessing was to produce a consistent dataset. Still, some discontinuity apparently was introduced starting with 1979, relative to the earlier (1948-1978) period when no satellite observations were available. This uncertainty, crucially important to the evaluation of trends, is addressed in a recent report on the Reanalysis project (Kistler et al., 2001).

North-Atlantic winds as the primary control of the surface-air temperature in Europe

In this section we examine the influence of the maritime-air advection on raising the winter temperature in Europe. The strength of the warm advection is quantified by a specific Index, I_{na} , of the ocean-surface southwesterlies over eastern North Atlantic. From the SSM/I dataset (Atlas et al., 1996), we evaluate at 45°N ; 20°W pentad-averages of the

wind speed from all the measurements which report the direction from the quadrant 180°-270°. When the direction is not southwesterly, the speed is counted to the average as a zero speed. The Index I_{na} derived by this approach is plotted in Fig. 1 for the winters 1989/90 and 1995/96, that is, for the 24 pentads from Dec. 2-6 to March 27-31.

Alongside I_{na} we plotted in Fig. 1 pentad-averaged T_{max} of the daily maximum temperature in Brussels, Belgium. We selected this Royal Meteorological Institute meteorological station, since its very long record establishes this dataset as suitable for evaluation of trends (Demarée et al., 2001). We note very large differences between the T_{max} in 1989/90 when compared to those in 1995/96, amounting to about 10°C for much of the winter. Based on detailed correlation analysis (Otterman et al., 1999), this difference in T_{max} can be attributed to the difference in the warm advection, quantified by I_{na} , the strength of the southwesterlies at the “gateway” to Europe. We note here that I_{na} exceeds 10 ms^{-1} for much of the warm 1989/90 period, but takes low values, generally below 4 ms^{-1} , for most of the cold winter 1995/96. The differences in the warm advection affect the surface-air temperature over vast areas, as can be seen from Fig. 2, where we compare February 1990 with February 1996. The sensitivity of the surface-air temperature to the low-level maritime-air advection is directly due to the large temperature difference prevailing in winter between the North Atlantic and the European continent (Otterman et al., 2000). The warming of the near-surface layer tends to produce a steeper lapse rate, that is, to destabilize the atmospheric conditions. These effects are analyzed in the next section.

Corollary effects of warm and moist low-level advection

The winters of 1989/90 and 1995/96 are well representative of opposite extremes in the NAO index. Sea level pressure gradients across 25°W longitude between latitudes 45-55°N were approximately twice as strong in 1990 as in 1996. Some of the largest sea level pressure differences between the two NAO states typically occur around the Bay of Biscay (Rogers, 1997). During periods such as early 1990, when storms migrate far

northeastward of Iceland, they can advect warm air and cloud cover as far east as central Siberia (Rogers and Mosley-Thompson, 1995).

Only monthly (or seasonal) data are relevant in climate studies, but insight into the phenomenology can be gained from a “single-moment” scenario. We illustrate the winter 1990 conditions in Fig. 3 presenting surface winds (from SSM/I and ECMWF) for Feb. 1, 1990, 00Z. We note a “STREAK” of southwesterlies directed toward France and England, where the wind speed exceeds 10 ms^{-1} .

The low-level warm advection in 1990 produced strong updrafts: ascent rates of up to -0.4 Pa s^{-1} were observed in monthly averages at 700 mb, which were especially strong over the ocean just to the west of Scandinavia. Such high monthly-average ascent rates persisted for more than a month. By comparison, in 1996 the monthly-average ascent rates at that level were reported generally as zero, with only occasional -0.1 Pa s^{-1} readings.

How the strong warm advection illustrated in Fig. 3 is affecting the state of the atmosphere 12 hours later, that is, on Feb. 1, 1990, 12Z, is shown in Fig. 4. We observe at 700 mb large cells of high ascent rates in a 270° “ring” around central Europe. In the strongest cells, one to the northwest of Ireland and the other centered on the southern coast of Scandinavia, the ascent rate tops -1.2 Pa s^{-1} . In cells over Finland, Spain and western Mediterranean, the ascent rates top -0.9 Pa s^{-1} .

The warm air masses advected in the 1989/90 winter are certainly moist, as we illustrate in Fig. 5: in central Europe at latitudes 52° -to- 60°N the total precipitable water is in February 1990 by some 5 kg m^{-2} higher than in February 1996. Higher moisture levels and steeper lapse rate combine to increase cloudiness: the total cloud cover reaches 60 to 70% for February 1990 as compared to 45 to 55% in 1996 (Fig. 6). In February the sun is low over the horizon in Europe, and the absorptivity (co-albedo) of the snow-covered surface is low, and thus absorption of insolation is hardly an important consideration for the surface temperature. Enhanced cloud cover and precipitable water vapour levels reduce heat loss to space. These corollary effects, by enhancing the greenhouse factor, reinforce the direct near-surface warming by the low-level warm advection from the North Atlantic.

Discussion and conclusions

Characterizing climatic conditions for a region involves specifying average values of the key climatic parameters, combined with their variability, that is, the statistics of departures from the averages. Poleward of 35°, the key climate parameter for agriculture and forestry (and for heating-fuel demand) is the surface temperature (both skin and the surface air, which are closely related). Surface temperatures dictate the beginning of planting and seeding at the end of winter, and the harvesting of crops before the next winter sets in. The winter/early-spring differences between 1989/90 and 1995/1996 that we discuss here, persisting at the level of 10°C for more than a week at a time for Brussels (see Fig. 1), is extremely large. This reported variability is entirely consistent with the variations in the February means characterizing central Poland (see our Table 1, or Table 4.1 for Warsaw, p. 78, in Woś, 1999). The fluctuations reported for Toruń, amount to 11.0°C and 11.7°C in the case of average monthly T_s and T_{max} , respectively (see Table 2). The above-described large temperature differences occurred over almost the whole continental mid-latitude Europe (see Fig. 2).

Our study indicates that the underlying cause of the winter temperature fluctuations in Europe is the variability of the surface winds over the North Atlantic. Such dependence constitutes an important teleconnection, as discussed by Hurrell (1996) and Otterman et al. (2000). The dependence of temperatures specifically in Poland on the circulation patterns was discussed by Niedźwiedź and Ustrnul (1994). The strong winter temperature trends at northern latitudes in Eurasia reported by Ross et al. (1996) may be the result of intensified advection from the North Atlantic. More quantitative assessment of the sensitivity of the temperatures in various European locations to the advection effects should be attempted.

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Fig. 1. Maximum daily temperature (T_{\max}) in Brussels, and the Index of the southwesterlies (I_{na}), pentad-averages for the December-to-March periods in 1989/90 and 1995/96.

Fig. 2. Surface air temperature (T_s in $^{\circ}\text{C}$) over the eastern North Atlantic and mid-latitude Europe (46°N to 60°N ; 10°W to 50°E), February 1990 at the top, February 1996 in the middle, their difference in the lowest figure.

Fig. 3. Surface winds (ms^{-1}) over the North Atlantic and Europe, Feb. 1, 1990, 00Z. (from SSM/I and ECMWF).

Fig. 4. Ascent rates at the 700 mb level (10 Pa s^{-1}), Feb. 1, 1990, 12Z (from ECMWF).

Fig. 5. As Fig.2, for the water vapor in the vertical column (kg/m^2).

Fig. 6. As Fig.2, for the total cloud cover (percent).

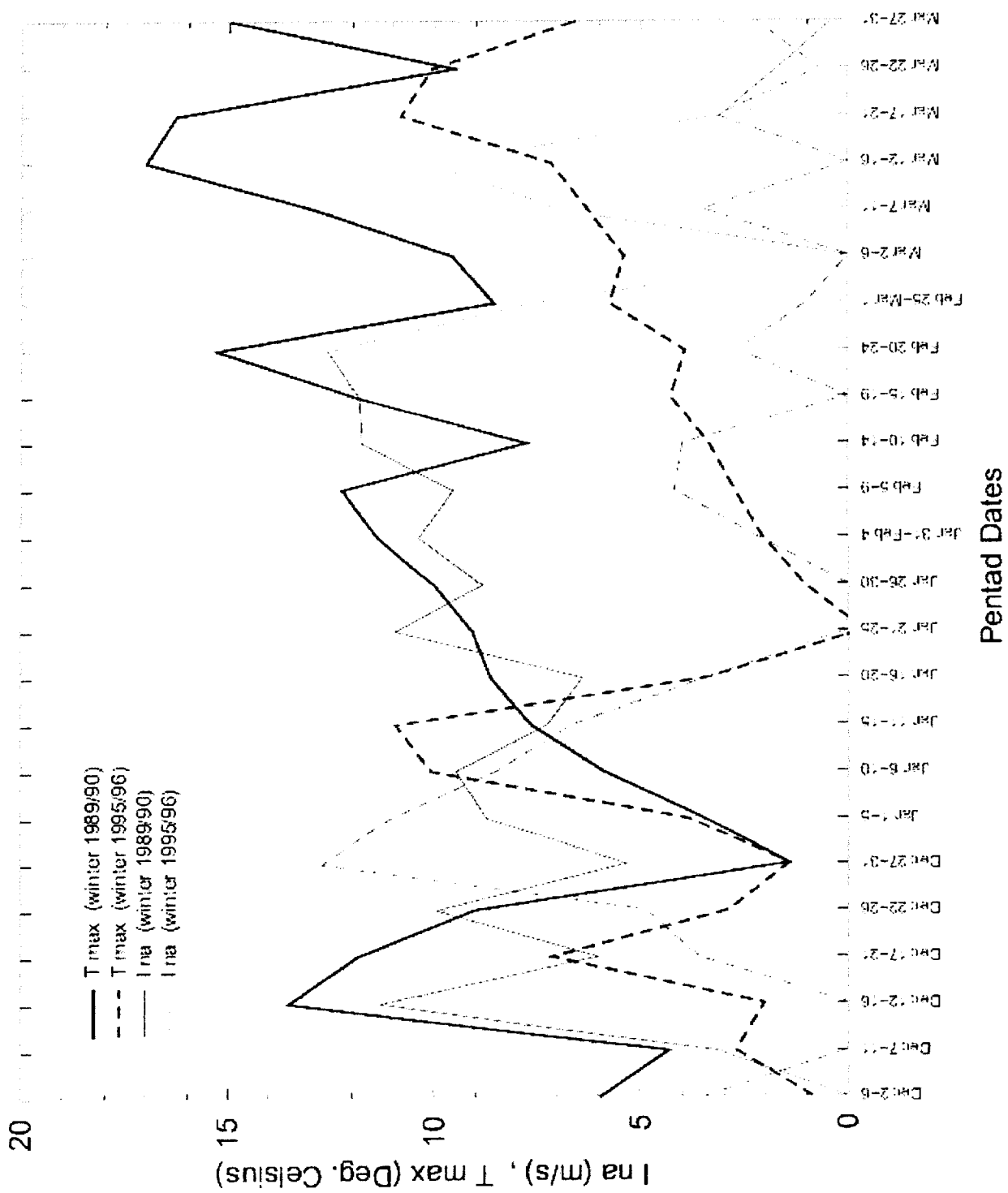


Fig. 1

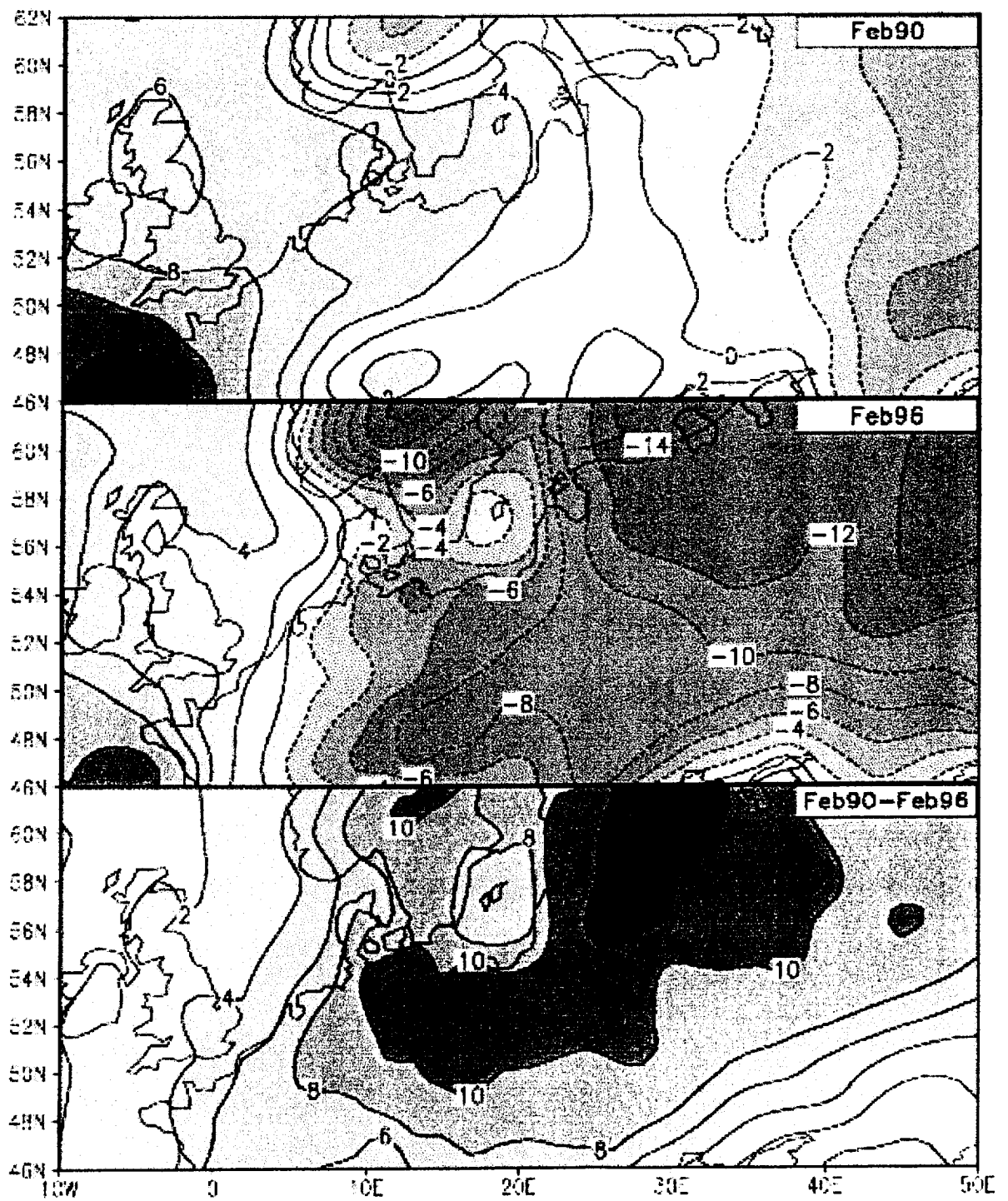


Fig 2

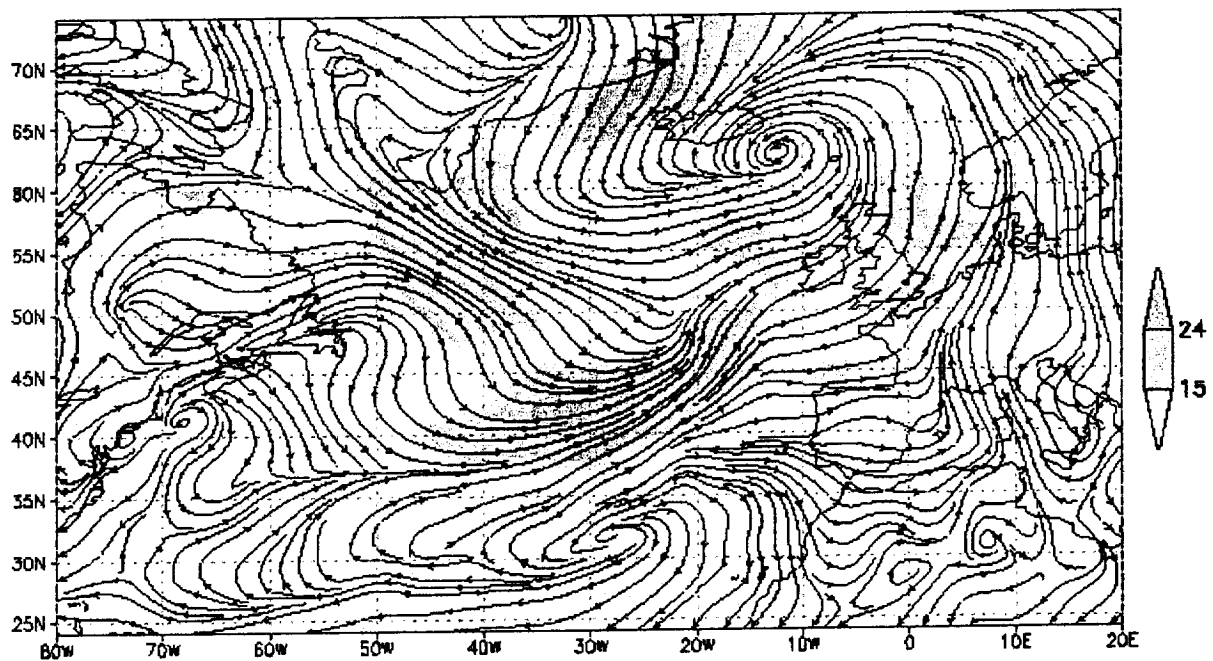


Fig 3. Surface winds (m s^{-1}) over the North Atlantic and Europe representative of the winter 1990 scenario; Feb. 1, 1990, 00Z (from ECMWF)

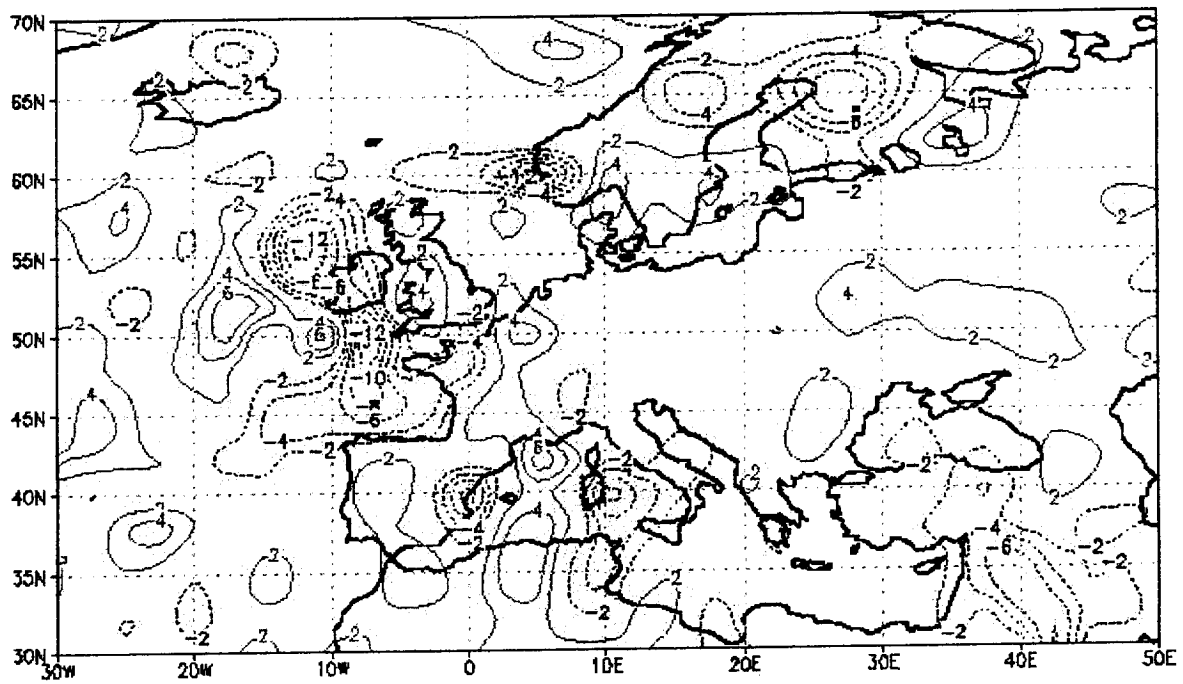


Fig. 4. Ascent rates at the 700 mb level (10 Pa s^{-1}); Feb. 1, 1990, 12Z (from ECMWF)

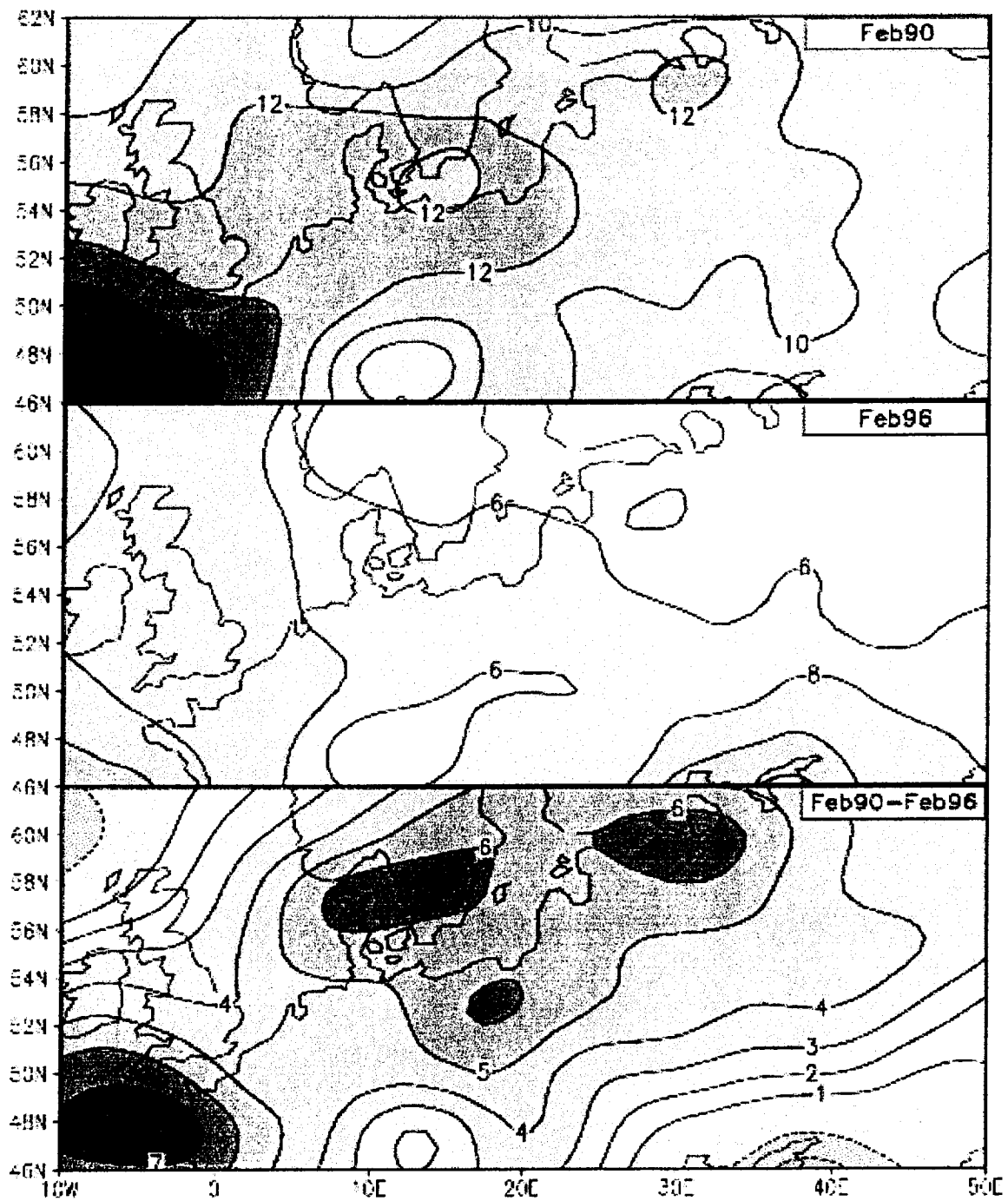


Fig 5

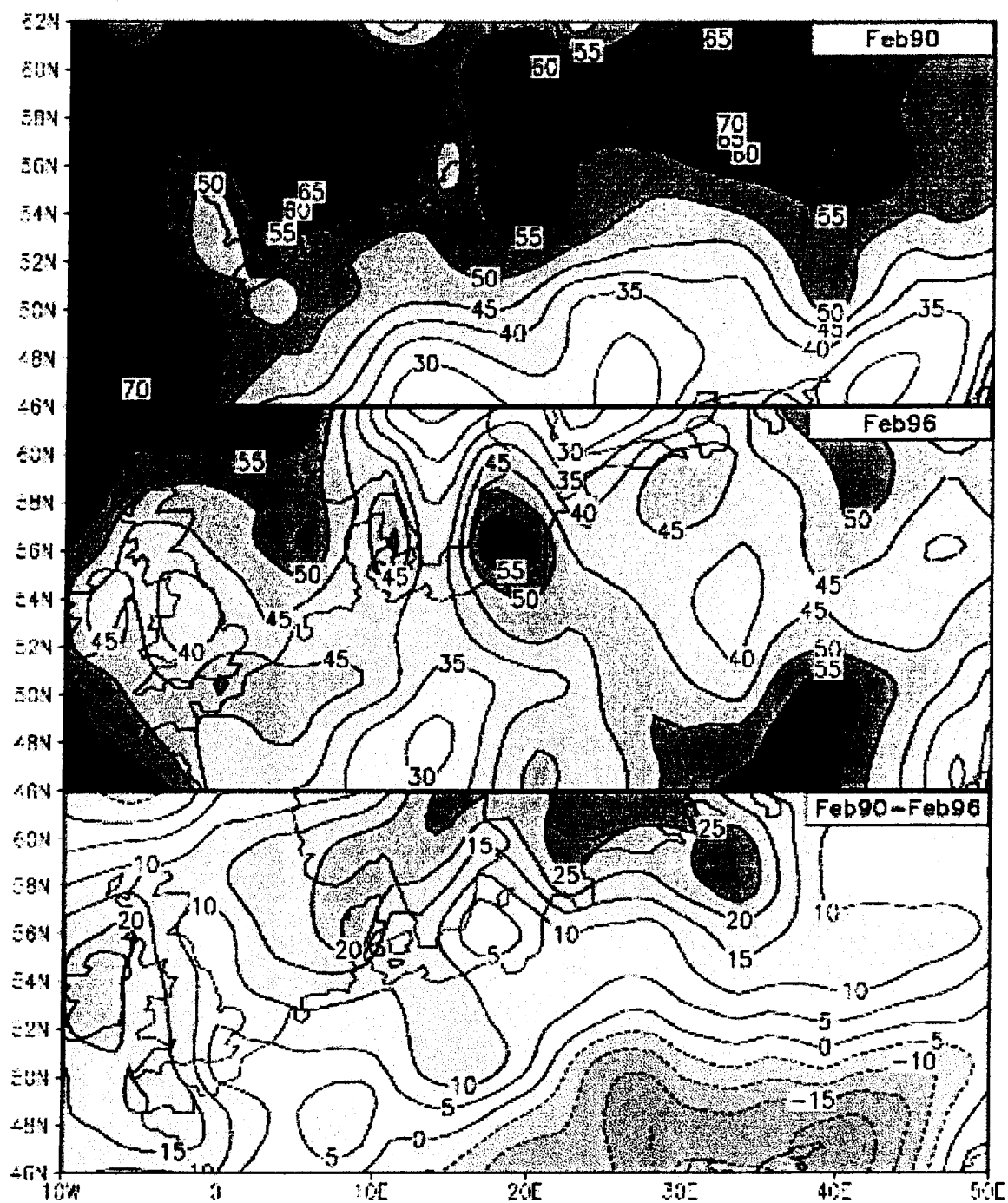


Fig 6